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RESEARCH ARTICLE

Development of technology for omega enriched mixed fat spread

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Abstract: This study aimed to develop an omega-enriched fat spread with improved nutritional benefits. Response surface methodology (RSM) was employed to optimize the levels of total fat, omega fat (combination of sesame oil and flaxseed oil) and diacetyl (flavour ingredient) in the fat spread. The results showed that the flavour score was mainly influenced by total fat and diacetyl content. The body and texture score increased with the addition of omega fat but decreased with increasing total fat. The colour and appearance score was not significantly affected by the any variables. Spreadability score decreased with lower omega fat and higher total fat content. Overall acceptability score was positively influenced by diacetyl content but negatively influenced by total fat content. The optimized product contained 53.4% total fat, 16.6% omega fat and 2.5 ppm diacetyl, exhibited desirable physico-chemical attributes, acceptable sensory properties, superior spreadability and a favourable fatty acid profile. Optimized product had 700 per cent more omega-6 and 1700 per cent more omega-3 fatty acids as compared to control fat spread and omega-6 to omega-3 fatty acids below 5:1.

Keywords: Omega-enriched fat spread, Cream, Sesame oil, Flaxseed oil, Omega fat, Mixed fat spread

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Introduction

Fat spread is a type of spreadable product made from vegetable oils or animal fats that have been processed and combined with other ingredients to make them spreadable. Fat spreads are often used as a substitute for butter and margarine and may be marketed as a healthier alternative due to their lower levels of saturated fats and hydrogenated vegetable oil (Kumari and Sharma, 2022). FSSAI (2011) has divided fat spread in three categories namely milk fat spread, mixed fat spread and vegetable fat spread. FSSAI standards for mixed fat spread are; Fat content should be not more than (NMT) 80% and not less than (NLT) 40% by weight (Rao and Devaraja, 2021); Moisture should be not more than (NMT) 56% and not less than (NLT) 16% by weight; Unsaponifiable matter of extracted fat should be not more than (NMT) 1% and Acid value of extracted fat should be not more than (NMT) 0.5%.

Nutritional lipids are a rapidly growing field. Consumers are learning more about the fat and oils that are beneficial to them, as well as the fat and oils that they should avoid. Omega-3 fatty acids are increasingly being promoted in products such as juice and bakery items, while drinks and snacks for weight management claim the benefits of conjugated linoleic acid (CLA). Omega-3 fatty acids are already identified to have cardiovascular health benefits, and there is growing evidence that they also have benefits for cognitive function (Goyal et al. 2014).

As the individual body is unable to produce PUFAs like omega-3 and omega-6, that is essential fatty acids, they should be acquired through diet. The proportion of omega-6 to omega-3 essential fatty acids in a western diet ranges from 15:1 to 16.7:1. This higher percentage of omega-6 to omega-3 fatty acids encourages the development of several illnesses, including autoimmune and inflammatory conditions, cancer, depression and heart disease. Omega-6 to omega-3 essential fatty acid ratios in the modern nutrition should vary from 1:1 to 5:1 in order to decrease the incidence of numerous chronic disorders (Simopoulos, 2002).

In light of the aforementioned issues, the current study aimed to develop a mixed fat spread with a variety of beneficial components. Vegetable oils such as flaxseed oil and sesame oil were used to improve the nutritional content and spreadability of the spread. Flaxseed oil contains approximately 50% alpha linolenic acid (ALA), which is an omega-3 fatty acid, while sesame oil contains approximately 50% linoleic acid, which helps to balance the ratio of omega-6 to omega-3 fatty acids (Saini and Keum, 2018). Flaxseed, sesame oil and milk fat is classical combo to balance the ratio of omega-6 to omega-3 fatty acid in diet and maintain it below 5:1.

Materials and Methods

Cream was procured from Anubhav Dairy, SMC College of Dairy Science, Kamdhenu University, Anand. Skim milk powder (SMP) from Anand local market of SAGAR brand. Sesame oil and flaxseed oil was procured from Anand local market of Til Sona brand and Hesthetic® brand respectively. CMC and guar gum was supplied by Molychem, Mumbai and HiMedia laboratories Pvt. Ltd. respectively. Common Salt (M/S Tata Chemicals Ltd.) and Diacetyl (DSM Nutritional Products India Pvt. Ltd. Mumbai) was used in the study. All the microbiological media utilized during research was procured from M/s Hi Media, Mumbai.

Preparation of Omega-enriched Fat Spread: Omega Enriched Fat Spread (OEFS) was prepared as suggested by Sethi and Balasubramanyam (2018). The product contained MSNF (10.0%) and salt (1.0%), combination of guar gum (GG) & carboxy methyl cellulose (CMC) (GG: CMC; 2:1) used as stabilizer @ 0.75 per cent and glycerol mono stearate (GMS) as emulsifier @ 0.25 per cent and they were pre-decided based on preliminary trials conducted. Experiments were conducted using three variables, namely total fat varying from 40-60 %, omega fat source oil (combination of sesame oil and flaxseed oil; 4:1) varying from 5 to 20 % and Diacetyl from 2 to 6 ppm as depicted in Table 1. Calculated amount of water along with other dry ingredients were mixed with fat base. Mix was then pasteurized at 71°C for 10 min followed by cooling to 4±1°C and packaged into pre-sterilized polypropylene (PP) cups (Fig. 1).

Analysis of omega enriched fat spread: Fat spreads were analyzed for total solids and ash (AOAC, 2000), Fat and Titratable acidity (% LA) (BIS, 1981), Protein (Manefee and Overman, ,1940), Peroxide value (meq / kg) (Kumar, 2011), TBA value (Absorbance 532nm) (King, 1962) and Free Fatty Acids (% oleic acid) (FSSAI, 2021). Hardness was measured by cone penetration value (Verma et al.

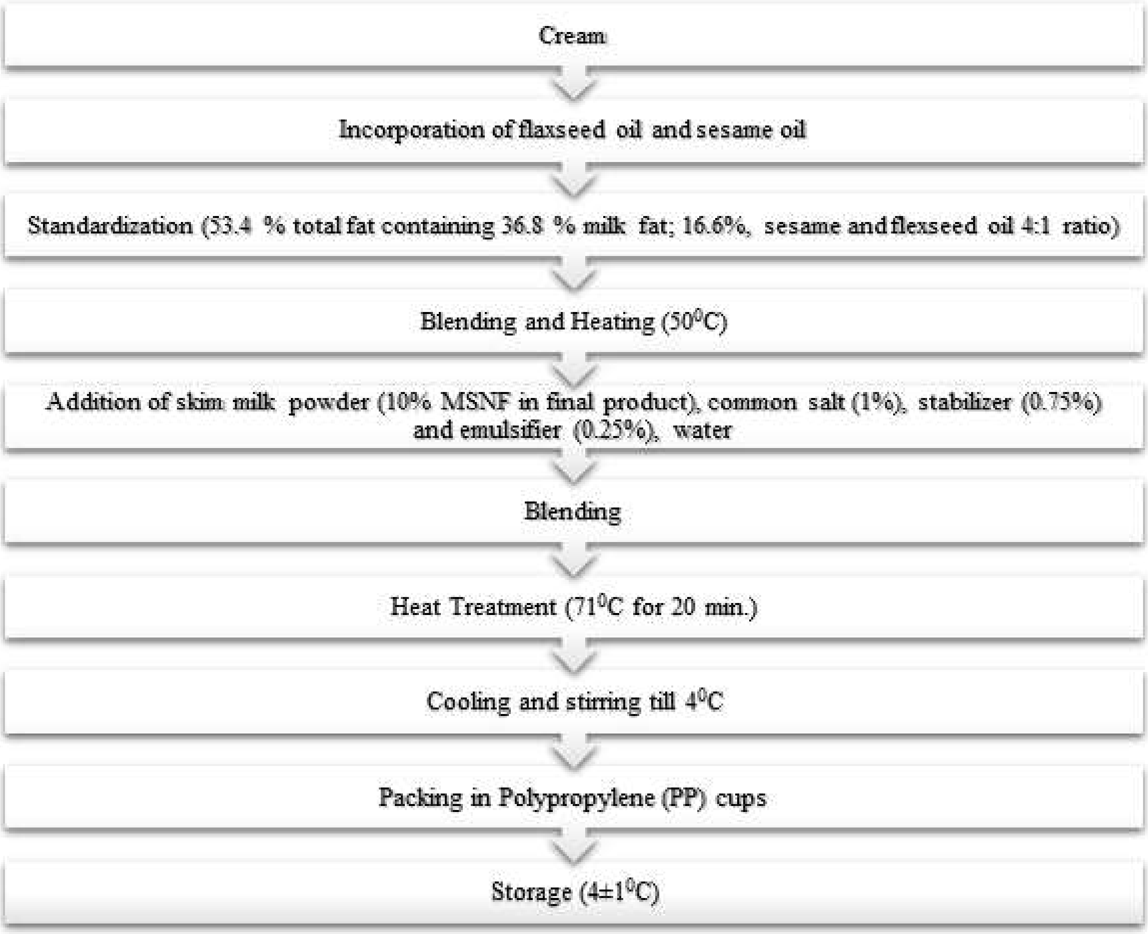

Fig. 1 Flow chart for the preparation of omega-enriched fat spread

1996) and sensory evaluation for different characteristics viz., flavour, body and texture, colour and appearance, spreadability and overall acceptability was carried out using 9-point hedonic scale (Lawless & Heymann, 2010).

Design experiment for optimization of formulation

A face-centred central composite design of the response surface methodology (RSM) technique was adopted for the optimization of the three variables viz., total fat, omega fat and diacetyl. Design software expert 13.0.5.0 suggested 20 combinations, including lower and upper limits for variables as depicted in Table 1. The data generated for different responses were analysed by Design Expert® software (13.0.5.0) (Stat-Ease, Inc., 2021 E. Hennepin Avenue, Minnepolis, USA). Sensory evaluation was conducted for all 20 experimental runs by a selected panel of 10 judges using 9-point hedonic scale.

A general polynomial equation given below was fitted for each response.

$$Y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_{11}x_{12} + a_{22}x_{22} + a_{33}x_{32} + a_{12}x_1x_2 + a_{23}x_2x_3 + a_{13}x_1x_3 + \text{Error term}$$

where : Y represents the predicted response; a_0 the constant coefficient; a_{11}, a_{22} and a_{33} denote quadratic coefficients; a_{12}, a_{23} and a_{13} denote interaction coefficients; x_1, x_2 and x_3 denote rate of addition of total fat, omega fat and diacetyl respectively.

Adequacy of the model was evaluated using coefficient of determination (R^2) and statistical significance was examined by F value. The effect of independent variables and individual responses were described at $P < 0.1$ and $P < 0.05$. t-test for two samples assuming equal variance was applied using Microsoft Excel for comparison of predicted values with the actual values of the responses.

Results and Discussion

Procedure of optimization for the production of OEFS was carried out with the goal of shaping the finest probable combination(s) of different levels of factors viz. total fat, omega fat and diacetyl that would lead to the most satisfactory product in terms of sensory attributes, compositional qualities, textural characteristics and physico-chemical properties. The goals or responses were set for obtaining the best possible combination. The data was analysed by response surface methodology using Design Expert Software 13.0.5.0.

Regression coefficients, Model-f value and precision of model are shown in Table 2. The R^2 (coefficient of determination) of models for checking the fitness of model, was greater than 0.8 indicating that variation in response could adequately be explained by formulation ingredients (Henika, 1982). The quadratic model was sufficient enough to explain the variability in the sensory attributes and for predicting and navigating purposes within design space. Adequate precision value (APV)

Table 1: Experimental design matrix and sensory score (9-point Hedonic scale) of Omega enriched fat spread

Run	T: Total fat (%)	O: Omega fat (%)	D: Diacetyl (ppm)	Flavour	Body & texture	Colour and Appearance	Spread-ability	Overall acceptability
1	40	5	2	5	7.85	6	7.25	6.52
2	60	5	2	7	5	6	5	5.75
3	40	20	2	5.25	8.25	6	7.85	6.83
4	60	20	2	5.1	7.75	5	7.25	6.27
5	40	5	6	5.5	7.85	6	5.5	6.21
6	60	5	6	6	5	5	5	5.25
7	40	20	6	5.05	7.85	7	7.75	6.9
8	60	20	6	5	7.75	6	6.75	6.37
9	33	12.5	4	5	8.75	6	7.75	6.87
10	66	12.5	4	7	8.5	5	6.25	6.68
11	50	0.1	4	8	5	7	5	6.27
12	50	25	4	8.5	7	7	7.75	7.56
13	50	12.5	0.6	7	8.98	9	8	8.25
14	50	12.5	7.3	5.25	8.95	9	8.75	8.00
15	50	12.5	4	9	8.9	9	9	8.97
16	50	12.5	4	8.8	9	9	9	8.95
17	50	12.5	4	9	8.75	9	9	8.93
18	50	12.5	4	9	9	9	9	9.00
19	50	12.5	4	8.75	9	9	9	8.93
20	50	12.5	4	9	8.8	9	9	8.95

greater than 4 in all sensory parameters suggested that model can be successfully used for optimization of product.

The probability value (p) showed the adequacy of the models so used to describe the effect of variables on different responses. The effect of level of total fat (T), omega fat source (O) and diacetyl (D) on the responses is shown in equations below. The sign and magnitude of coefficients indicate the effect of the variable on the responses. The models thus developed with coded variables are as follows:

Flavour = (8.47946) + (0.305019 * T) + (0.148602 *O) + (0.658621*D) + (-0.533125 TO) + (-0.139687 *TD) + (-0.141563* OD) + (-1.33575 *T^2) + (-0.187246 *O^2) + (-0.223362 *D^2)

Body and texture = (8.92102) + (-0.517281 *T) + (0.721679 *O) + (0.0352386 * D) + (0.6375 * TO + 0.025 *TD) + (-0.025 * OD) + (-0.232708 * T^2) + (-1.18824 * O^2) + (-0.0249416 * D^2)

Colour and appearance = (8.94393) + (-0.281007 *T) + (-0.100149 *O) + (0.159489 *D) +(-0.125 *TO) + (-0.0625 *TD) +(0.1875 *OD) + (-1.48387 * T^2) + (-0.975533 * O^2) + -0.0614385 * D^2)

Spreadability = (8.97457) + (-0.588026 *T) + (0.773195 *O) + (0.133428 *D) + (0.14375 *TO) + (0.084375 *TD) + (0.071875 *OD) + (-0.833148 *T^2) + (-1.06179 *O^2) + (-0.0866426 *D^2)

Overall acceptability = (8.90817) + (-0.221033 *T) + (0.305516 *O) + (0.202009 *D) + (0.08125 *TO) + (-0.009375 *TD) + (0.0609375 *OD) + (-0.957986 *T^2) + (-0.930114 *O^2) + (-0.1206 *D^2)

Sensory scores of omega enriched fat spread varied for flavour from 5.0 to 9.0, Body and Texture from 5.0 to 9.0, Colour and Appearance from 6.0 to 9.0, Spreadability from 5.0 to 9.0 and Overall acceptability from 5.25 to 9.0. Thus a change in level of Total fat, Omega fat source and diacetyl had significantly impacted the sensory properties of Omega Enriched Fat Spread (OEFS). Also non-significant interactions were represented by equations between all parameters i.e. level of total fat, omega fat source and diacetyl content.

Effect of Total Fat, Omega Fat and Diacetyl on Flavour of OEFS

Flavour, a vital measure for determining the superiority of the food product determines its consumers' acceptability. Figure 2 (A) depicts the positive effect of Total fat (T) and Diacetyl (D) level on flavour score and such effect was significant ($P < 0.05$). In case of extreme values, total fat (T^2), omega fat (O^2) and diacetyl (D^2) levels had significant negative effect ($P < 0.05$) on flavour score. It suggested that the maximum flavour score obtained in fat spread when the total fat was about 50 per cent, omega fat 12.5% and diacetyl content of 4.0 ppm. It might be because, at higher concentrations of diacetyl lead to undesirable harsh flavour. Patange et al. (2022) reported similar effect of diacetyl which had significant effect on flavour score in ghee based low fat spread.

From the Table 2 the Model F-value of 7.92 implies the model is significant. There is only a 0.17 per cent chance that an F-value this large could occur due to error. The adequate precision value of 7.487 i.e., greater than 4 is desirable, recommends the use of this response to navigate the design.

Table 2: Regression coefficients and ANOVA fitted quadratic model for the responses of omega enriched fat spread

Terms	Sensory scores (9-point hedonic scale)				
	Flavour	Body & Texture	Colour & Appearance	Spreadability	Overall acceptability
Intercept	8.793	8.921	8.943	8.970	8.080
T: Total fat	0.502**	-0.517*	-0.281	-0.588*	-0.220
O: Omega fat	-0.172	0.721*	-0.100	0.773*	0.305
D: Diacetyl	0.479*	0.035	0.159	0.133	0.202**
TO	-0.331	0.637*	-0.125	0.143	0.081
TD	-0.084	0.025	-0.062	0.084	-0.009
OD	0.009	-0.025	0.187	0.071	0.060
T^2	-1.282*	-0.232	-1.483*	-0.833*	-0.957*
O^2	-0.494*	-1.188*	-0.975*	-1.061*	-0.930*
D^2	-0.309*	-0.024	-0.061	-0.086*	-0.120*
			Model fit statistics		
R^2	0.876	0.914	0.907	0.934	0.905
Model F-value	7.92	11.94	10.93	15.89	10.66
APV	7.4871	11.6711	10.014	11.8504	8.665
Suggested Model	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

* significant level at 5 % level, ** significant level at 10 % level

Effect of Total Fat, Omega Fat and Diacetyl on Body and Texture of OEFS

A body relates to level of stiffness and texture relates a lumpy, grainy and coarse characteristic which is important physical attribute in the product. It decides the acceptance of the product by consumers. In present study, as depicted in Table 1 and Table 2, increasing the level of total fat decreased the body and texture score significantly ($P < 0.05$), while increasing the quantity of omega fat increased the body and texture score significantly ($P < 0.05$). However, the combination of total fat and omega fat (TO) had significant positive effect on body and texture score. For quadratic level, omega fat (O^2) had significant negative effect on body and texture score. It was found that addition of omega fat, higher in unsaturation, increased the body and texture score significantly however, outside above the given range it led sharp decline in body and texture score significantly.

Omega fat increased, body and texture score also increased because combination of milk fat (containing higher saturated fat) and omega fat (higher unsaturated fat) gave adequate firmness, while extreme higher value of omega fat (O^2) led to poor standability and hence reduced score. This could be because of lower freezing point of unsaturated fat and it might have resulted in very soft body which is not satisfactory in the case of fat spread. Whereas if higher milk fat is present (containing higher saturated fat) resulted in more stiff product with difficulty in spredability at refrigeration temperature. Prajapati et al. (1991) advocated replacement of 20 parts of milk fat with vegetable oil in fat spread containing 40% total fat which resulted in optimum body and texture score.

As seen in the Table 2, the adequate precision value of 11.67 i.e., greater than 4 is desirable, recommends the use of this response to navigate the design. The Model F-value of 11.94 implies the model is significant.

Effect of Total Fat, Omega Fat and Diacetyl on Colour and appearance of OEFS

The visual perception of a fat spread's colour and appearance (C&A) determines its acceptability by the consumer. Variables linear level (T, O and D) and interactive level (T^2, O^2 and D^2) had non-significant effect on colour and appearance score. For quadratic level, total fat (T^2) and omega fat (O^2) had significant ($P < 0.05$) negative impact on colour and appearance score. Total fat and omega fat if present beyond their given range than it led to sharp decrease in colour and appearance score. Such effect could be because of both milk fat and omega fat at higher level resulted in duller yellowish product that might have led to reduction in bright and glossy white appearance in final product. Though in different product, El-Hadad et al. (2011) reported 80:20 ratio of milk fat and palmolein in chocolate spread that had highest colour and appearance score.

It could be seen from Table 2, that the adequate precision value of 10.014 which is greater than 4 is desirable, recommends the use of this response to navigate the design. The Model F-value of 10.93 implies the model is significant.

Effect of Total Fat, Omega Fat and Diacetyl on Spreadability of OEFS

Spreadability a crucial characteristic of spread type foods is the single-most essential, desirable feature and is true for of a fat spread. It is an expression that refers to how effortlessly a product is evenly distributed across the given surface. The fact that fat spreads can be distributed regardless of low temperature is their greatest admirable quality.

The spreadability score of fat spread ranged from 5 to 9 (out of 9) as shown in Table 1 and pictorial depiction in Figure 2 (b). The sample containing lower amount of omega fat (containing higher unsaturation) and higher total fat (containing higher saturation) had lower spreadability score compared to samples containing higher amount omega fat and lower amount of total fat. Total fat (T) showed it's significant ($P<0.05$) negative impact on spreadability score. While omega fat (O) showed its significant positive effect ($P< 0.05$) on spreadability score, which could be explained by the presence of omega fat i.e., sesame oil and flaxseed oil both contains very high content of unsaturated fat which has lower melting point i.e., that remains in liquid condition even at refrigeration temperature and thus fat spread remains more spreadable. For quadratic level, increasing the values of any of three variables (T^2, O^2 and D^2) above or below their extreme values in the given range lead to sharp decrease in the spreadability score. From above findings, it was concluded that by replacing certain amount of milk fat with healthy omega fat (flaxseed oil and sesame oil) can improve spreadability of fat spread.

Blending of milk fat and vegetable oil has been tried by many scientists to improve spreadability of fat spread. A whey protein concentrate, milk fat and olive oil-based spread developed by (Kumar, 2011), in which milk fat was 10 per cent and olive oil was 30 per cent having better spreadability. Pavithra et al. (2024) advocated combination of cream and sunflower + flaxseed oil (80:20) for improving spreadability and overall acceptability of functional fat spread. Sunflower oil was used as a substitute of 30 per cent of the dairy fat by Kulkarni and Rama Murthy (1988), and they discovered that the spreadability at low temperature increased compared to control sample.

From Table 2, the adequate precision value of 11.8504 which is greater than 4 is desirable, recommends the use of this response to navigate the design. The Model F-value of 15.89 implies the model is significant. There is only a 0.01 per cent chance that an F-value this large could occur due to error.

Effect of Total Fat, Omega Fat and Diacetyl on Overall acceptability of OEFS

Numerous elements that may be connected to the person, the food and the atmosphere where it is consumed have an impact on how nutrition is accepted. Overall acceptability is a hedonic (pleasure)-based metric that is impacted through a food's sensory characteristics (Hadfield et al. 2003). The overall acceptability score of fat spread ranged from 5.25 to 9 as shown in Table 1.

Diacetyl (D) showed its significant ($P \leq 0.1$) positive effect on overall acceptability score as seen in Figure 1 (C). For quadratic level, all three levels i.e., total fat (T^2), omega fat (O^2) and diacetyl content (D^2) have significant ($P \leq 0.05$) negative impact. Thus, it was concluded that differing amount of total fat, omega fat or diacetyl content below or above of their given range led to very sharp decline in overall acceptability score. To obtain optimized product, all three variables should be within their given range for overall acceptance. Maureen et al. (2024) prepared a typical blend in a weight ratio with rapeseed oil (58.28%), anhydrous milk fat (AMF) (27.68%), stearin of AMF (12.08%), DMG (1.36%), and PS (0.58%) for preparation of mix fat spread. They concluded from their work that a mixture of oil and dairy fat provides essential fatty acids, particularly from the n-3 series. This supply of long-chain unsaturated fatty acids influences the liquid–solid phase balance within the crystalline network and there by improves spreadability and overall acceptability. Prajapati et al. (1991) reported excellent consumer acceptability by replacing 20 parts of butter fat with vegetable oil. Patange et al. (2022) also reported incorporation of diacetyl at linear level impacted overall sensory quality of dairy spread.

From Table 2, the adequate precision value of 8.666 i.e., greater than 4 is desirable, recommends the use of this response to navigate the design. The Model F-value of 10.66 implies the model is significant. There is only a 0.05 per cent chance that an F-value this large could occur due to error.

Considering the parameters and their limits, the RSM recommended the one most suitable solution. Recipe of optimized omega enriched product as per recommended RSM software is given in Table 3. As per suggested solution from RSM analysis for fat spread, total fat, omega fat and diacetyl should be 53.4%, 16.6% and 2.5 ppm respectively. Optimized product was prepared by adding milk fat, sesame oil, flaxseed oil and diacetyl as suggested by RSM. The predicated values for flavour, body and texture, colour and appearance, spreadability and overall acceptability for OEFS were 8.03, 8.37, 8.17, 8.90 and 8.34. It is evident from the Table 3 that the actual values were not significantly (P>0.05) different from predicted values with respect to all attributes. Hence, it was confirmed that the selected level of addition of total fat, omega fat and diacetyl is most suitable for the preparation of omega enriched fat spread with optimum sensory attributes.

Table 3: Optimized product recipe and comparison of predicated and actual response

OPTIMIZED PRODUCT RECIPE

Ingredients	Quantity (g)	Fat (g)	MSNF (g)
Cream (60% fat, 4.5% SNF)	612	367.2	27.3
SMP (1% fat, 96% SNF)	76	0.8	72.9
Omega oil	166	166	-
Stabilizers	7.5	-	-
Emulsifiers	2.5	-	-
Common Salt	10	-	-
Water	126	-	-
Total	1000	534	100

Predicted and actual response values for optimal spread formulation

Sensory response	P-value	Predicated value*	Actual value@	Calculated t-value#	Level of significance
Flavour	0.899	8.03	8.04	-0.134	Non-significant
Body & texture	0.129	8.37	8.24	1.904	Non-significant
Colour & Appearance	0.581	8.17	8.07	0.598	Non-significant
Spreadability	0.208	8.90	8.99	-1.496	Non-significant
Overall acceptability	0.911	8.34	8.36	-0.118	Non-significant

Note: *No significant difference was found between predicted and actual response values at 5 percent level of significance.*

* Predicted values of Design Expert 13.0.5.0 package

@ Actual values are mean of seven trials for prepared fat spread

t-values found non-significant at 5% level of significance

Tabulated t-value = 2.776 (Calculated t-value less than tabulated value)

Compositional Characteristics of OEFS: Fat content of the fat spread was 53.57 per cent, which was in conformity with FSSAI standards of fat for Mixed Fat Spread. Moisture content was 34.67 per cent which was well within the legal limit prescribed by FSSAI standards for blended fat spread (Not more than 56% and not less than 16%). The ash and protein content of the prepared fat spread was 2.08 per cent and 3.41 per cent respectively. Higher amount ash content might be due to incorporation of common salt and SMP. The carbohydrate content was 6.27 per cent. Spread prepared with above compositional attributes had better flavour, body & texture, colour and appearance, improved spreadability and overall acceptability.

Physico-chemical Properties of OEFS: Physico-chemical properties such as per cent lactic acid, FFA, peroxide value, TBA value and Fatty acid profile of mixed omega fat spread was analyzed. Acidity and FFA value of optimized fat spread was 0.124 % LA and 0.101 % oleic acid respectively. The observed value for FFA was within the legal limit as per FSSAI (0.25 per cent by weight calculated as oleic acid). Peroxide value indicates likeliness of becoming rancid while TBA value indicates degree of oxidation. Peroxide and TBA value of optimized fat spread was 0.084 meq/1 kg fat and 0.037 respectively. The observed value for peroxide in the present study was well within the limit provided for oils (peroxides should be below 15 meq O_2/kg oil for refined oils according to the Codex Alimentarius).

Sensory Properties of OEFS: Developed blended fat spread was analysed for sensory characteristics and was found highly acceptable in terms of all sensorial parameters. Sensory study was done by 9-point hedonic scale and the mean values of all the sensory attributes were higher than 8.04 which showed an excellent quality spread with superior spreadability and better overall acceptance for the developed product**.**

Table 4 Fatty acid profile of milk fat spread (T_1) and omega enriched fat spread (T_2)

Parameters	T_1 (%)	T_2 (%)
Butyric acid (C4:0)	2.556	1.782
Caproic acid (C6:0)	1.505	1.024
Caprylic acid (C8:0)	0.898	0.592
Capric acid (C10:0)	1.993	1.322
Lauric acid (C12:0)	2.432	1.663
Myristic acid (C14:0)	10.435	7.302
Palmitic acid (C16:0)	32.482	25.849
Stearic acid (C18:0)	14.219	11.928
Oleic acid (C18:1)	24.311	27.214
Linoleic acid (C18:2)	1.458	11.887
Linolenic acid (C18:3)	0.196	3.599
Arachidic acid (C20:0)	0.322	0.422
Behenic acid (C22:0)	0.062	0.150
Omega-6 to omega-3 ratio	7.43	3.31

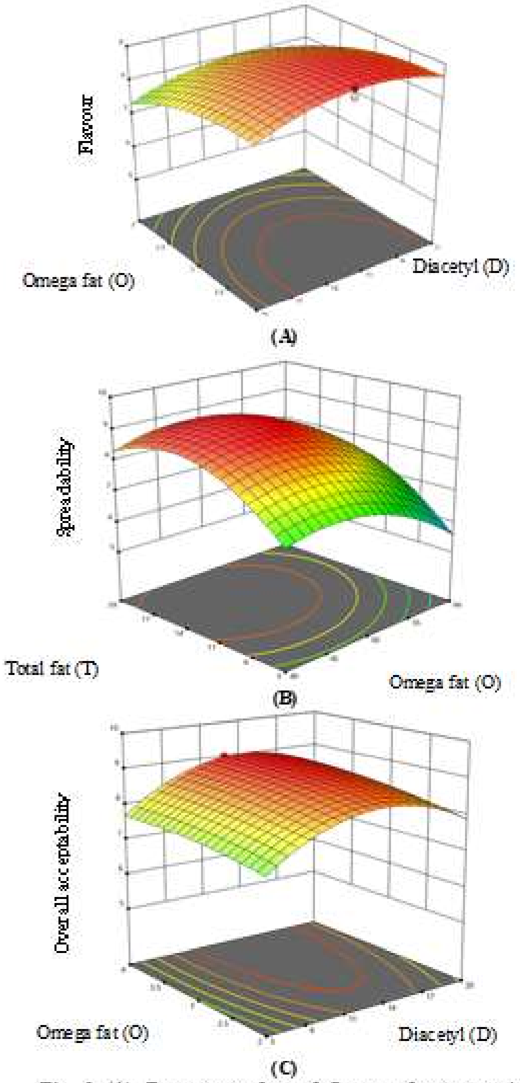

Fig. 2 (A) Response surface of flavour of omega-enriched fat spread as influenced by level of omega fat and diacetyl level, (B) Response surface of spreadability of omega-enriched fat spread as influenced by level of total fat and omega fat level, (C) Response surface of overall acceptability of omega-enriched fat spread as influenced by level of omega fat and diacetyl level

Rheological Characteristics of OEFS: Hardness of the spread was assessed from the cone penetration value by using cone penetrometer. The cone penetration value at 4^0C of optimized fat spread was 28.82 mm signifying better spredability.

Microbiological Analysis of OEFS: Optimized omega enriched fat spread incorporated with combination of sesame oil and flaxseed oil was subjected for their microbiological analysis. An excellent microbiological status with aerobic plate count of 3.71 $\log_{10}$ (cfu/g) and yeast and mold count was observed 5.83 cfu/g for optimized fat spread. Coliform count was Absent/g, indicating proper hygienic conditions maintained during development and preparation of omega enriched fat spread.

Fatty acid profile of optimized fat spread: Fatty acid composition of the optimized omega enriched fat spread (containing sesame oil, flaxseed oil and milk fat) as well as control spread (containing only milk fat spread) were analysed with help of NDDB CALF laboratory as per method delineated in AOAC (2023) 996.06 22nd Edn. by Gas Chromatography Flame Ionized Detector. The result obtained from the analysis of both the samples is shown in Table 4. Linoleic acid increased from 1.458 % to 11.887 % and Linolenic acid content increased from 0.196 % to 3.599 % and omega fat ratio reached to desirable level (less than 5) of 3.31.

Conclusion

It is concluded that all the study parameters such as standardization of rate of total fat, omega fat and diacetyl content played a significant role in obtaining omega enriched fat spread with high acceptability and consistent quality. An acceptable quality of omega enriched fat spread could be prepared using 53.4% total fat containing 16.6% omega fat source (Sesame and flexseed oil 4:1 ratio) and 2.5 ppm diacetyl as flavourant. The method standardized for the manufacture of omega fat enriched fat spread is very simple and can suitably employ for commercial production.

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